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Parton Densitites at High–x

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Reliable knowledge of parton distributions at large x is crucial for many searches for new physics signals in the next generation of collider experiments. Although these are generally well determined in the small and medium x range, it has been shown that their uncertainty grows rapidly for $x > 0.1$. We examine the status of the distributions in light of new questions that have been raised about "large-x" parton distributions, as well as recent measurements which have improved the parton uncertainties.

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1 Introduction

Four years ago the CDF collaboration reported[1] an excess of jet events at large transverse energy over perturbative Quantum Chromodynamics (QCD) calculations. A possible explanation for this effect was a larger than expected gluon distribution[2] at large x. Three years ago the deep-inelastic scattering (DIS) experiments at HERA reported a low statistics excess of events[3] at large Q^2. This led to speculation that part of this excess could be attributed to a lack of knowledge of the quark distributions[4] at large x, and could possibly be related to the jet events which are produced by a combination of quark and gluon scattering. Both excesses produced a large number of papers about the possible implications for physics beyond the Standard Model, emphasizing the need for much better knowledge of parton distributions[5] at large x.

In the past few years there has been considerable progress towards understanding some of the uncertainties in the individual measurements that contribute to our knowledge of large-x parton distributions (PDFs); but, in some cases this has led to an *increase* in the uncertainty of the large-x PDFs, rather than a reduction. We will review the recent analyses, and mention future measurements which may help clarify this situation.[b]

2 d/u Ratio

The ratio of the density of down quarks to that of up quarks in the proton has changed in the most recent CTEQ[7] and MRST[8] analyses due to the new W

[a]Presented by F. Olness.
[b]For a comprehensive presentation of these issues, see Ref. [6].

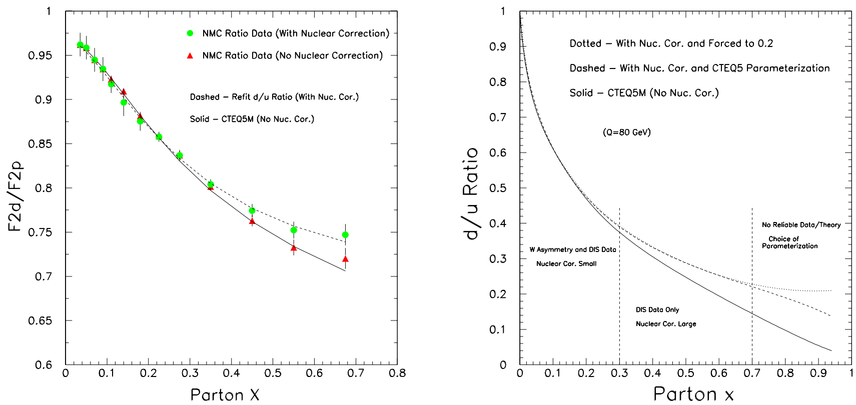

Figure 1: a) The measured ratio of muon scattering off deuterium and hydrogen targets, from the NMC experiment, is shown with and without the nuclear corrections described in the text. The (lower) solid line is CTEQ5M which was fit to the data with no nuclear corrections, while the (upper) dashed line is a fit to the data with the nuclear corrections, altering the d/u ratio. b) The d/u ratio is shown for the three global fits described in the text. Also shown are the three different regions of x and the relevant measurements in each region: *i*) DIS and W Asymmetry data for $x < 0.3$, *ii*) DIS only for $0.3 < x < 0.7$, and *iii*) no data for $0.7 < x$.

lepton-asymmetry data from CDF,[9] as well as the NMC ratio measurement of deuterium/hydrogen scattering.[10] For many years the basic assumptions about the parameterization of this ratio and the use of the DIS data have been relatively unchallenged, but this has changed. The two main reasons to question these assumptions are: 1) the behavior of the d/u ratio as $x \to 1$, and 2) possible nuclear binding effects in the deuteron.

To illustrate the different possibilities, a new series of fits were performed within the context of the CTEQ5 global analysis.[7] The nuclear binding corrections were included as well as fits with a modified behavior of d/u as $x \to 1$. We find we can get a good fit to all the data with neither correction, or with the nuclear binding corrections added but with any d/u behavior as $x \to 1$. Figure 1a shows the NMC ratio data with and without the deuteron correction. The lower (solid) curve is CTEQ5M, while the upper (dashed) curve is a new fit to the corrected data, again with the standard CTEQ5 parameterization which forces d/u to zero as $x \to 1$. Both are good fits to the NMC data, as is a new third option (not shown since it lies precisely on the dashed curve) which includes both the nuclear corrections and the changed d/u parameterization. Figure 1b shows the d/u ratio resulting from these three fits at Q=80 GeV (there is very little evolution dependence in this ratio). All

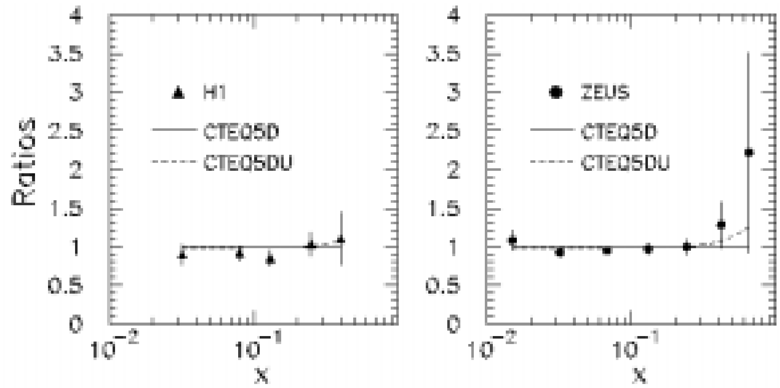

Figure 2: Positron-induced charged current data from H1 and ZEUS, along with NLO QCD calculations using parton distributions fit *with* (CTEQ5DU) and *without* (CTEQ5D) nuclear corrections to the fixed target data (see text).

three are viable candidates for the d/u ratio, and the upper and lower ones could quite reasonably be considered upper and lower bounds. Figure 1b also includes vertical lines to distinguish the three regions of x involved in this study, and to help explain why the different effects can be treated as independent. For $x < 0.3$ the W lepton-asymmetry data and the NMC ratio data are both very precise *and* the nuclear corrections to the NMC data are insignificant. The two measurements agree so the d/u ratio is very well constrained in this region. Unfortunately the present W asymmetry data end near $x = 0.3$, precisely where the nuclear corrections to the NMC data become significant. Therefore with any reasonably flexible parameterization one can get a spread of d/u ratios for $0.3 < x < 0.7$ (the middle region of the plot) simply by changing the nuclear correction, and still fitting the W asymmetry and NMC data. Finally for the largest x values, we note that the NMC data end near $x = 0.7$; therefore many different extrapolations to $x \to 1$ are possible, with or without nuclear corrections. Clearly the issues for the three different regions are quite independent.

It is worth noting that if $d/u \to 0.2$ as $x \to 1$, then there *must* be some nuclear corrections in order to fit the NMC data. The previous discussion shows that the converse is not necessarily true. However if appreciable binding effects are present in the deuteron, then it is perhaps more natural for d/u to go to a constant than to zero, which would require a fairly sharp downturn near $x = 1$. Assuming that d/u does not suddenly increase as $x \to 1$, this constant is unlikely to be larger than 0.22, since that is where the last NMC data point lies. But any constant between 0.05 and 0.2 would be a reasonable extrapolation and is not constrained by present data.

The best way to constrain the d quark in the future is with high luminosity HERA measurements of positron-induced charged current interactions. Figure 2 show the most recent H1[11] and ZEUS[12] charged current measurements. For the H1 data the cuts are $Q^2 > 1000$ GeV^{2}and y <0.9, while for ZEUS the cut is $Q^2 > 200$ GeV^2. They are compared to a NLO QCD calculation using the standard CTEQ5D (DIS scheme) set of parton distributions, which are fit without the binding corrections to the NMC data. This provides a good description of the data, although there is a hint of a low statistics excess in the ZEUS data. The dashed curves in the ratio plots are a second DIS scheme fit, which we label CTEQ5DU, including binding corrections but with the CTEQ5 parameterization ($d/u \rightarrow 0$) corresponding to the dashed curve (in the $\overline{MS}$ scheme) in Figure 1b. Since the data are below $x < 0.7$ the fits with $d/u \rightarrow 0.2$ give the same result as CTEQ5DU in this plot. Parton distributions similar to the dashed and solid curves were used to estimate the required luminosity to distinguish them. The result is that 500 pb^{-1} of delivered positron luminosity (250 pb^{-1} in each of the two experiments)[13] is needed to achieve a 2 standard deviation separation. This is clearly a large data set but not impossible with the forthcoming HERA upgrade. We think it is vital that the HERA program continue until this issue is settled.

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